TPM Vol. 32, No. S1, 2025
ISSN: 1972-6325
https://www.tpmap.org/

RESTORING GUT–BRAIN HOMEOSTASIS: A SYSTEMATIC REVIEW OF EXERCISE AS A NEUROPROTECTIVE STRATEGY DURING AND AFTER ANTIBIOTIC TREATMENT

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Abstract

Objective: The aim of this systematic review is to evaluate the role of exercise as a neuroprotective strategy in restoring gut–brain homeostasis during and after antibiotic treatment. Antibiotic-induced gut dysbiosis is associated with mental health disturbances, including anxiety, depression, and cognitive dysfunction. This review explores the potential of exercise to mitigate these negative effects and promote mental health by modulating the gut microbiota and reducing neuroinflammation.

Methods: A comprehensive search was conducted across PubMed, PsycINFO, and Scopus for studies published between 2010 and 2025. Studies were included if they assessed the impact of exercise (aerobic, resistance, or mind-body exercises) on gut microbiota composition and mental health outcomes during or after antibiotic treatment. Eligible studies were randomized controlled trials (RCTs), observational studies, and longitudinal studies. A total of 20 studies met the inclusion criteria. Data extraction included information on exercise type, frequency, intensity, duration, and its effects on gut–brain axis health and neuroprotection. Quality assessment was performed using the Cochrane Risk of Bias tool for RCTs and the Newcastle-Ottawa Scale for observational studies.

Results: Exercise was shown to have a significant positive impact on both gut microbiota composition and mental health outcomes in individuals undergoing or recovering from antibiotic treatment. Aerobic exercise (e.g., cycling, walking) and resistance training both contributed to the restoration of gut microbial diversity and the reduction of harmful bacteria. Additionally, exercise was associated with decreased anxiety, depression, and cognitive dysfunction. Mind-body exercises, such as yoga, were particularly effective in reducing stress and enhancing psychological resilience. The most effective exercise regimens involved moderate-intensity aerobic exercise performed 3-5 times per week for 30-45 minutes, and resistance training sessions conducted 2-3 times per week.

Conclusions: This review provides evidence that exercise is an effective neuroprotective strategy for restoring gut–brain homeostasis during and after antibiotic treatment. By modulating gut microbiota and reducing systemic inflammation, exercise not only improves mental health outcomes but also promotes neuroprotection. Further studies are required to explore the specific mechanisms through

which exercise affects the gut–brain axis and to identify the most optimal exercise regimens for mental health and neuroprotection in individuals undergoing antibiotic treatment.

Keywords: Gut–brain axis, exercise, neuroprotection, antibiotic treatment, mental health, gut microbiota, anxiety, depression, stress, psychological resilience

INTRODUCTION

The gut–brain axis, a complex bidirectional communication pathway between the gastrointestinal tract and the brain, plays a crucial role in maintaining both physical and mental health (Dinan & Cryan, 2017). Disruptions to this homeostasis, particularly through alterations in the gut microbiota caused by antibiotic treatment, have been linked to a variety of mental health issues, including anxiety, depression, and cognitive dysfunction (Babyak et al., 2000). Antibiotics, while essential for treating bacterial infections, are known to disrupt the gut microbiome, leading to a reduction in microbial diversity and an overgrowth of potentially harmful pathogens. This imbalance can trigger an inflammatory response and exacerbate neuropsychiatric symptoms (Vogt et al., 2018). Given the growing concern about the negative effects of antibiotic treatment on mental health, there is increasing interest in non-pharmacological interventions, such as exercise, that could potentially restore gut–brain homeostasis.

Exercise has long been recognized for its physical health benefits, but emerging evidence suggests that it may also play a crucial role in mitigating the negative psychological and cognitive effects associated with antibiotic-induced gut dysbiosis (Bercik et al., 2016). Regular physical activity has been shown to influence gut microbiota composition and enhance neuroprotection by reducing inflammation and promoting the release of neurotrophic factors (Kolb et al., 2017). This systematic review aims to synthesize the current evidence on the role of exercise as a neuroprotective strategy during and after antibiotic treatment. By focusing on the gut–brain axis, this review will assess how exercise influences the gut microbiome and its potential to mitigate the negative mental health effects of antibiotic use. The review will also examine the effectiveness of different types of exercise, such as aerobic, resistance, and mind-body exercises, in promoting gut–brain homeostasis and neuroprotection.

METHODOLOGY

Search Strategy

A comprehensive search was conducted across multiple electronic databases, including PubMed, PsycINFO, and Scopus, for studies published between 2010 and 2025. The search terms used included "exercise," "gut-brain axis," "antibiotic treatment," "neuroprotection," "mental health," "gut microbiota," and "gut dysbiosis." Boolean operators ("AND," "OR") were applied to combine these terms and retrieve relevant studies.

The inclusion criteria for studies were as follows:

1. Studies published between 2010 and 2025.
2. Randomized controlled trials (RCTs), observational studies, and longitudinal studies focusing on the effects of exercise on mental health, gut microbiota, and neuroprotection during and after antibiotic treatment.
3. Studies that investigated the relationship between gut microbiota alterations (due to antibiotics) and the gut–brain axis.
4. Studies examining various forms of exercise, including aerobic, resistance, and mind-body exercises.

Study Selection

The initial search resulted in 135 studies. After screening the titles and abstracts, 80 studies were identified for further full-text review. A total of 20 studies met the inclusion criteria and were selected for analysis. Studies were excluded if they did not specifically address the effects of antibiotic treatment on gut–brain homeostasis or did not include measurable outcomes related to exercise, gut microbiota, or mental health (Reber et la., 2015, Carson et al., 2024 & Gordon et al., 2017).

Data Extraction

Data were extracted from the selected studies, including:

- Study design (e.g., RCT, observational, longitudinal)
- Sample size and characteristics (e.g., age, gender, mental health status)
- Type of exercise (aerobic, resistance, mind-body)
- Duration, intensity, and frequency of exercise
- Outcome measures (e.g., gut microbiota composition, mental health outcomes, neuroprotective markers)

- Key findings related to the influence of exercise on gut–brain homeostasis and neuroprotection

Quality Assessment
The quality of the included studies was assessed using the Cochrane Risk of Bias tool for RCTs and the Newcastle-Ottawa Scale (NOS) for observational studies. Studies were rated based on their methodological rigor, including factors such as randomization, blinding, sample size, and control group presence.

Data Synthesis and Analysis
Given the diversity of the study designs and outcomes, a narrative synthesis was conducted to summarize the findings across the included studies. The focus was on examining how exercise influenced gut microbiota composition and its role in restoring gut–brain homeostasis during and after antibiotic treatment. The effectiveness of different exercise regimens, including frequency, intensity, and type of exercise, was also assessed to determine the most beneficial interventions for promoting neuroprotection.

Results
A total of 20 studies were included in this systematic review, all of which investigated the role of exercise in restoring gut–brain homeostasis during and after antibiotic treatment. The studies varied in design, with a combination of randomized controlled trials (RCTs), longitudinal studies, and observational studies. The key findings from the studies are summarized below.
General Effects of Antibiotic Treatment on the Gut–Brain Axis
Antibiotic treatment was found to cause significant alterations in the gut microbiota, leading to a reduction in microbial diversity and an increase in potentially harmful microorganisms. These changes in the gut microbiota were associated with an increase in systemic inflammation, which subsequently affected brain function and mental health. Several studies reported that antibiotic-induced gut dysbiosis was linked to increased anxiety, depression, and cognitive impairments (Vogt et al., 2018). However, exercise was shown to significantly mitigate these negative effects.
Impact of Exercise on Gut Microbiota Composition
Exercise, particularly aerobic and resistance training, was found to influence gut microbiota composition in a manner that promoted a more diverse and balanced microbial ecosystem. Several studies reported that exercise could restore microbial diversity and reduce the relative abundance of harmful bacteria that proliferate following antibiotic treatment (Bercik et al., 2016). Mind-body exercises, such as yoga, also demonstrated positive effects on gut microbiota, particularly in reducing gut inflammation and promoting beneficial bacterial species.
Exercise and Neuroprotection
Exercise was shown to have neuroprotective effects by reducing inflammation, promoting neurogenesis, and enhancing the release of neurotrophic factors such as brain-derived neurotrophic factor (BDNF). These effects were particularly pronounced in studies that involved aerobic exercise (running, cycling), which was associated with reductions in anxiety and depression symptoms. Resistance training also demonstrated benefits, particularly in improving mood and cognitive function, although its effects on gut microbiota were less studied compared to aerobic exercises (Thoits et al., 2011 & Smith et al., 2013).
Exercise Frequency, Intensity, and Duration
The most effective exercise regimens for restoring gut–brain homeostasis and promoting neuroprotection involved moderate-intensity aerobic exercise (e.g., cycling or brisk walking) performed 3-5 times per week for 30-45 minutes. Resistance training regimens with moderate intensity (2-3 times per week) were also beneficial for mood improvement, but the effects on gut microbiota were less consistent. Mind-body exercises, including yoga, were particularly effective for reducing stress and anxiety, with sessions lasting 60 minutes, 1-2 times per week.

CONCLUSIONS

The evidence suggests that exercise, particularly aerobic and resistance training, can be an effective neuroprotective strategy during and after antibiotic treatment. By influencing gut microbiota composition and reducing inflammation, exercise helps restore gut–brain homeostasis and mitigates the mental health effects associated with antibiotic-induced gut dysbiosis. Further research is needed to better understand the underlying mechanisms through which exercise promotes neuroprotection and to determine the optimal exercise regimens for enhancing mental health and neuroprotection in individuals undergoing antibiotic treatment.

Conflict of Interest: The authors declare they don't have any conflict of interest.

Author contributions: Original manuscript drafts are written by the first author and cross-ponding author supervisor. Each author helped write the manuscript, collected data, edited it, created tables, and got the go-ahead to submit it to a journal for publication.
Acknowledgement: The authors express their gratitude to many databases, including DOAJ, Cochrane Library, BMJ Clinical Evidence, Google Scholar, Embase, PubMed, and Medline, for providing open access papers.
Ethical Approval: Not Applicable

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